

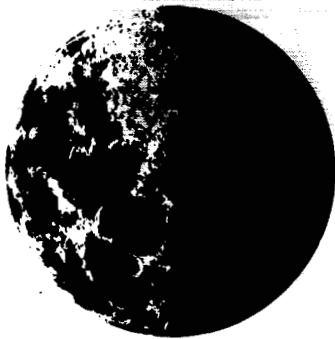


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COMMAND MODULE HEAT SHIELD ABLATOR
SUBSYSTEM DEVELOPMENT PLAN
NAS9-150

July 1965



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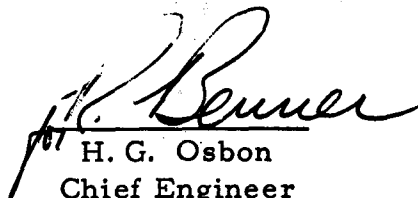
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TECHNICAL REPORT INDEX/ABSTRACT

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ABSTRACT

This document defines the analyses and testing leading to full lunar orbital rendezvous qualification. At the subsystem level, it provides direction and guidance for detail planning, provisioning, and other development activities performed by S&ID and its subcontractors. This plan also provides technical requirements for integrated subsystem tests on ground and flight test vehicles.



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1.0 INTRODUCTION

1.1 PURPOSE AND SCOPE

The Command Module Heat Shield Ablator Subsystem Development Plan (SDP) defines the analyses and testing leading to full lunar orbital rendezvous (LOR) qualification. At the subsystem level, it provides direction and guidance for detail planning, provisioning, and other development activities performed by S&ID and its subcontractors. This SDP also provides technical requirements for integrated subsystem tests on ground and flight test vehicles.

1.2 RELATIONSHIP TO OTHER DOCUMENTS

This SDP has been prepared in accordance with the documentation requirements of the Apollo Program Plan, SID 62-223, except for the qualification test ground rules, which are in accordance with the CSM Technical Specification, Block I, SID 63-313, and the CSM Technical Specification, Block II, SID 64-1344. The SDP supports the flight and ground programs specified in MDS-8, Revision 3, dated 1 March 1965, and the Development Test Plan (DTP), SID 64-1707. It also provides a cross correlation of development logic.

1.3 REVISIONS

To ensure that this SDP maintains its value as a directive document, it will be revised as required. Revision caused by technical direction will be incorporated upon receipt of a "Contract Advice" notice stating NAA's position. S&ID-proposed revisions to this SDP are to be submitted to C. A. Morant, Department 696-400.



2.0 DEVELOPMENT PROGRAM SUMMARY

The following major milestones summarize program activities for the subsystem.

Block I trajectory definition	(NAA)
Block I design criteria definition	(NAA)
100-percent release of Block I structure drawings	(NAA)
Basic material and process selection	(NAA & AVCO)
100-percent drawing and specification release	(AVCO)
Block I structure shipment	(NAA)
SC 009 and 011 flights	
SC 008 thermal-vacuum testing	
Block II trajectory definition	(NASA)
Block II heating definition	(NAA)
100-percent release of Block II structure drawings	(NAA)
100-percent release of Block II drawings	(AVCO)
Block II structure shipment	(NAA)
SC 2TV-1 thermal-vacuum testing	
SC 017 and 020 flights	



3.0 SUBSYSTEM MISSION OBJECTIVE

The command module heat shield ablator subsystem has the single function of minimizing heat input into the command module structure during the atmospheric entry. When subjected to the environments specified in either SID 63-313 (Block I spacecraft) or SID 64-1344 (Spacecraft 017 and 020 and Block II spacecraft), the ablator must maintain the steel structure-ablator interface temperature below 600 F until:

- Forward compartment jettison
- Earth impact for the crew compartment
and aft compartment (Block I)
- Main parachute deployment (Block II)



4.0 SUBSYSTEM DESCRIPTION

4.1 SUBSYSTEM PERFORMANCE

The ablative material and the process for its attachment to the heat shield structure are being developed by AVCO Research and Advanced Development Corporation, Lowell, Massachusetts, to conform to the S&ID requirements outlined in Procurement Specification MC 364-0001 and Specification Control Drawing ME 364-0001 for Block I and Procurement Specification MC 364-0004 and Specification Control Drawing ME 364-0004 for Block II. The AVCO design uses an open-cell fiberglass honeycomb matrix bonded to the steel heat shield structure and subsequently filled with a low-density ablative material (Avcoat 5026-39). Avcoat 5026-39 is an epoxy resin-fiber composite (for strength) mixed with phenolic resin microballoons (to minimize density and thermal conductivity). Special design considerations are required in the areas where the ablator interferes with other subsystems (launch escape tower leg wells, joints between compartments, windows, RCS engines, etc.).

The heat shield ablator subsystem performs its required function of minimizing heat flow into the command module structure by the charring of the ablative material applied to the command module exterior. This charring results in reradiation of some of the incident energy and absorption of additional energy in ablator degradation. Finally, the uncharred material serves as an insulator to slow the flow of conducted heat to the structure.

The subsystem is totally passive, with no intentional design margins of safety or redundancies. There are no basic differences between the Block I and Block II materials or designs. The material distribution and detail design of the Block II heat shield ablator, however, are different from Block I because of the difference in detail mission requirements.

4.2 SUBCONTRACTOR RESPONSIBILITY

The command module heat shield ablator subcontractor is responsible for:

1. Selection of basic materials and processes
2. Design of ablator thickness



3. Thermostructural analysis of the composite steel structure-ablator during all mission phases
4. Detail mechanical and thermal design of the ablative material
5. Fabrication of the ablator on NAA-furnished steel structures
6. Qualification testing of panels representative of the ablator and its attachment to the steel structure
7. Monitoring of the NAA structural analysis of the steel structure in sufficient detail to suggest tradeoffs, design optimization, etc.

The S&ID responsibilities in support of the subcontractor are as follows:

1. Definition of aerodynamic heating and loads to be used in the design of the subsystem
2. Detail structural analysis of the steel structure
3. Fabrication of the steel structure
4. Monitoring of subcontractor design, analysis, and fabrication efforts

The interrelationships of the NAA and AVCO efforts are also shown in Figure 5-1.



5.0 DEVELOPMENT PLAN

5.1 ANALYSES

Analysis is the basis for all flights, because it is not possible to simulate all the entry flight parameters during ground testing.

5.1.1 Subcontractor

There are no subcontractor analyses other than those associated with subsystem design. The planned and actual analytical efforts of the subcontractor and the resultant designs are documented as follows:

1. Basic development plan (AVCO report RAD-SR 62-113)
2. Final aerodynamics report (AVCO report RAD-SR 64-55)
3. Summary report (AVCO report RAD-SR 64-137)
4. Regular monthly progress reports
5. Final stress analysis
6. AVCO production design drawings (401xxx and 402xxx series)
7. AVCO material and process specifications as listed in the AVCO bi-monthly 201 Series report

5.1.2 Contractor

The contractor is primarily concerned with analyses of the as-built vehicle, designed to basic specifications, for planned missions. These analyses are documented with varying degrees of formality within S&ID, ranging from internal letters to DEI presentations.

5.2 MATERIAL AND PROCESS DEVELOPMENT

Ablator material and process development, including associated mechanical and thermal properties tests, etc. (Figures 5.1 and 5.2), is a major portion of this subsystem development program.



5.3 DEVELOPMENT TESTS

Material screening, material properties, and design data tests are listed in Table 5-1.

5.4 QUALIFICATION TESTS

The qualification test program for this subsystem is presented in Tables 5-2 through 5-4. This testing, in support of Spacecraft 012, is not in accordance with the qualification ground rule requiring two mission cycles as a test condition. For a one-mission system, without reserve for a second mission (no refurbishment capability), a two-mission cycle test would have no value.

5.5 MAJOR GROUND TEST

A thermal-vacuum test performed to the mission cold soak and thermal gradient conditions is required to support certification of Spacecraft 012 in the areas of ablator structural performance and intercompartment gap sizes. Without such a test, sufficient confidence in the analysis to man-rate the subsystem is not possible.

5.6 FLIGHT TESTS

Because ground test facilities do not permit either large specimen testing or simultaneous achievement of all the entry heating parameters, flight testing is required. Spacecraft 009 and 011, flown at or beyond the bounds of the Spacecraft 012 heating environment, will certify the ablator for manned flight on Spacecraft 012. Also, such flights will both increase confidence in the ability of Spacecraft 017 and 020 to fly lunar orbital entries and provide additional data for analytical extrapolation of the Spacecraft 017 and 020 heat shield flight test data to the Block II envelope trajectory conditions. Spacecraft 017 and 020 flight testing, at the bounds of the Block II heating environment, is required to man-rate Spacecraft 101.



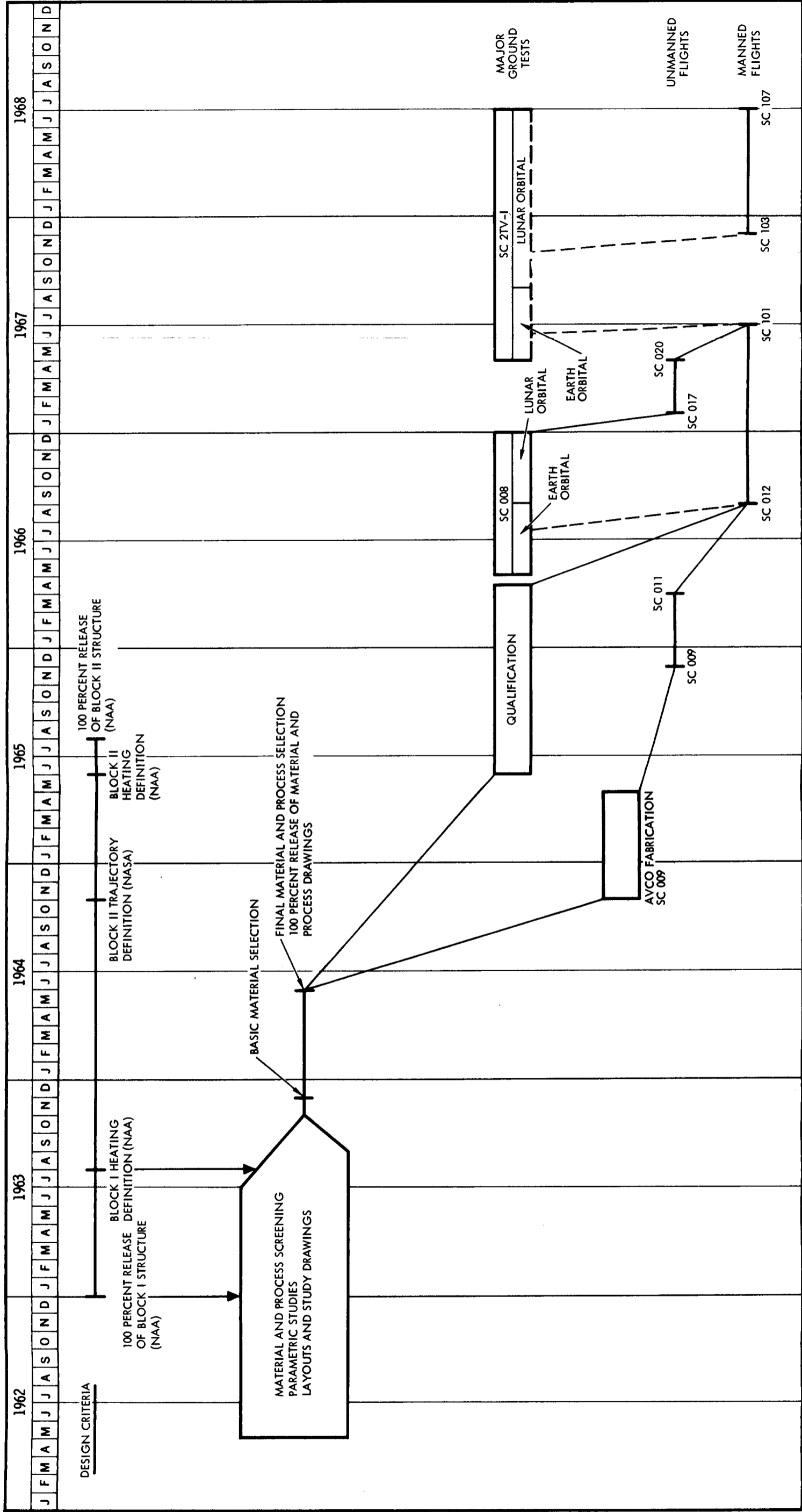


Figure 5-2. Development Schedule for Command Module Heat Shield Ablator



Table 5-1. Development Tests

Type of Test	Number of Tests
THERMAL, OPTICAL, AND ABLATIVE PROPERTIES EVALUATION	
Thermal conductivity	256
Specific heat	90
Heat of degradation	30
Optical	321
Solar simulation	77
Model 500 plasma arc (Q* and ascent)	436
Orbital vehicle reentry simulator (OVERS) stagnation heating	558
OVERS two-dimensional	109
10-milliwatt plasma arc (turbulent pipe specimen)	136
STRUCTURAL PROPERTIES EVALUATION	
Cold soak	63
Flat panel reentry	11
Temperature gradient	17
Beam	44
Stress concentration	30
Curved panel reentry	3
Panel sequential and cyclic	37
Special design problem	41
Dynamic	7
Repair	3
MECHANICAL PROPERTIES EVALUATION	
Tension	1960
Compression	720
Shear	24
Thermal and moisture strain	35
Bond	1300



Table 5-2. Test Sequence for Main Ablator

Test	Panel Number*							
	1	2	3	4	5	6	7	8
PHASE A, MISSION								
Acceptance	1	1	1	1	1	1	1	1
Humidity	2	2	2	2				
Salt fog	3	3						
Vibration plus launch load	4	4	3	3				
Vacuum-high temperature	5	5			2	2		
Vacuum-low temperature	6	6			3	3		
Vacuum-temperature cycling			4	4			2	2
Temperature gradient	7	7			4	4		
Entry heating	8	8	5	5				
Loading and vibration								
PHASE B, OFF LIMITS								
Vibration - temperature					5	5		
Low temperature loading							3	
Entry heating-loading								3
*Test sequence is shown for each panel.								



Table 5-3. Test Sequence for Abort Tower Well Ablator

Test	Specimen Number*				
	1	2	3	4	5
PHASE A, MISSION					
Acceptance	1	1	1	1	1
Humidity	2	2			
Salt fog	3				
Vibration plus launch load	4	3			
Vacuum-high temperature	5		2		
Vacuum-low temperature	6		3		
Vacuum-temperature cycling		4		2	2
Entry heating-loading and vibration	7	5		3	
PHASE B, OFF LIMITS					
Vibration-temperature			4		
Entry heating-loading				4	
*Test sequence is shown for each specimen.					

Table 5-4. Test Sequence for Special Test Samples of Ablator

Test	Special Test Samples of Main Ablator										Special Test Samples of Abort Tower Well Ablator								
	4-5/8 In. Dia., 1/2 In. Thick			0.371 In. Dia., 1-1/4 In. Long			3/4 In. Dia., 2 In. Long		3 In. O.D., 1-1/4 In. I.D., 5 In. Long		Instrumented Plug, 3/4 In. Dia., 1-1/2 In. Long in a 3-1/2 In. Dia. Shroud		4-5/8 In. Dia., 1/2 In. Thick		0.371 In. Dia., 1-1/4 In. Thick				
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Acceptance	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
High vacuum plus temperature	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Thermal conductivity at 250 F	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Before charring	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
After charring at 1000 F	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
After charring at 1750 F																			
Specific heat																			
Heat of ablation (laminar thermochemical). Ablator temperature-time response is obtained at:																			
50 Btu/ft ² /sec and 10,000 Btu/lb									3	3									
150 Btu/ft ² /sec and 10,000 Btu/lb											3								
Heat of ablation (turbulent thermochemical). Ablator temperature-time response is obtained at:																			
50 Btu/ft ² /sec and 10,000 Btu/lb												3							
150 Btu/ft ² /sec and 10,000 Btu/lb													3						